

## CLAIMS

1. A mouse interface device for interfacing a user's motion with a host computer and providing force feedback to said user, said mouse interface device comprising:

5 a mouse object contacted and manipulated by a user and moveable in a planar workspace with respect to a ground surface;

10 a planar linkage including five members rotatably coupled to each other, wherein said linkage is arranged such that a first base member is rotatably coupled to a ground member, a first link member is rotatably coupled to said first base member, a second base member is rotatably coupled to said ground member, and a second link member is rotatably coupled to said first link member and said second base member, wherein said mouse object is coupled to said planar linkage at said coupling of said first link member and said second link member;

15 a plurality of electromagnetic actuators providing forces in said planar workspace of said mouse object, said forces caused by interactions between an electric field and a magnetic field, wherein each of said actuators includes a coil portion integrated with one of said members of said linkage and a magnet portion coupled to said ground surface through which said coil portion moves, and wherein said actuators are controlled from commands output by said host computer; and

20 a plurality of sensors coupled to said ground surface and separate from said actuators, said sensors detecting movement of said coil portions of said actuators, wherein said sensor provides a sensor signal including information describing said movement of said coil portion from which a position of said mouse object in said planar workspace are determined.

2. A mouse interface device as recited in claim 1 wherein said first base member and said second base member pivot about a single axis with respect to said ground member.

25 3. A mouse interface device as recited in claim 1 wherein said first base member and said first link member are symmetrically arranged to said second base member and said second link member.

30 4. A mouse interface device as recited in claim 1 wherein said coil portion of one of said actuators is an end of said first base member, wherein a wire coil is integrated in said coil portion, and wherein said coil portion of the other one of said actuators is an end of said second base member, wherein a wire coil is integrated in said end of said second base member.

5. A mouse interface device as recited in claim 1 wherein said actuators are spaced apart from each other.

6. A mouse interface device as recited in claim 5 wherein a base portion of one of said actuators is used as a base portion of a different actuator.

7. A mouse interface device as recited in claim 3 wherein said first and second base members are coupled to a rotation point not at an end of said base members, where one end of each base member integrates said coil such that said coil is spaced from said rotation point of said member, thereby providing mechanical advantage to forces generated by said actuator on said base members.

8. A mouse interface device as recited in claim 5 wherein said sensors are digital encoders, and wherein said ends of said first base member and said second base member include an encoder arc which moves past a grounded emitter and detector.

9. A mouse interface device as recited in claim 8 wherein said encoder arc includes a number of equally spaced marks, said marks being detected by said encoders when said member moves.

10. A mouse interface device as recited in claim 5 wherein said sensor includes an emitter and detector and a rotating arc, said arc including an opaque portion and a transparent strip, said transparent strip being skewed such that its distance from a center of rotation of said arc varies along the length of said strip.

11. A mouse interface device as recited in claim 1 wherein at least one of said sensors includes an emitter of a beam of electromagnetic energy and a detector that detects said beam, wherein said beam is guided to said detector by a light pipe, said sensor outputting a sensor signal indicative of said motion.

12. A mouse interface device as recited in claim 3 wherein said mouse object is rotatably coupled to said coupling between said first link member and said second link member.

13. A mouse interface device as recited in claim 2 further comprising a stop mechanism for limiting movement of said mouse object in four directions in said planar workspace to a desired area.

14. A mouse interface device as recited in claim 13 wherein said stop mechanism includes a guide opening provided in a pad surface on which said mouse object slides, wherein a portion of said linkage protrudes through said guide opening and engages sides of said guide opening to provide said limits to said movement in said planar workspace.

15. A mouse interface device as recited in claim 14 wherein said linkage is positioned beneath said pad surface, and wherein said coupling to which said mouse object is coupled extends through said guide opening.

16. A mouse interface device as recited in claim 1 wherein said mouse object is supported by a support separate from said linkage and provided between said mouse object and said ground surface, wherein said support includes a roller coupled to said mouse object.

17. An interface device as recited in claim 3 further comprising an indexing input device allowing said user to change the offset between a position of said mouse object and a location of a cursor displayed on a display screen by disabling the mapping between said cursor and said mouse object.

18. A mouse interface device for providing force feedback to a user of said interface device, wherein a host computer is coupled to said mouse interface device and implements a graphical environment with which said user interacts, said interface device comprising:

a support base provided on a grounded surface, said base including a support surface provided above said grounded surface;

a mouse object physically contacted and manipulated by a user in two degrees of freedom with respect to said support surface, wherein said mouse object contacts said support surface;

a mechanical linkage including a plurality of members, said linkage coupled to said mouse object and providing said two degrees of freedom, wherein a portion of said linkage is positioned beneath said support surface and wherein a portion of said linkage extends through said support surface and is coupled to said mouse object;

a plurality of actuators, said actuators providing a force on said mouse object in said two degrees of freedom; and

a sensor detecting movement of at least one of said members of said linkage, wherein said sensor includes an emitter that emits a beam of energy and a detector that detects said beam, wherein both said emitter and said detector of said sensor are coupled to said ground surface.

19. A mouse interface device as recited in claim 18 wherein said linkage includes a base member coupled to said ground surface and a link member coupled to said mouse object, wherein

a portion of said link member extends through said support surface and is coupled to said mouse object.

20. A mouse interface device as recited in claim 18 wherein said linkage includes a planar linkage including five members rotatably coupled to each other, such that a first base member is rotatably coupled to a ground member, a first link member is rotatably coupled to said first base member, a second base member is rotatably coupled to said ground member, and a second link member is rotatably coupled to said first link member and said second base member, wherein said mouse object is coupled to said planar linkage at said coupling of said first link member and said second link member, wherein said coupling extends through said support surface.

21. A mouse interface device as recited in claim 18 wherein said portion of said linkage extending through said support surface extends through a guide opening in said support surface.

22. A mouse interface device as recited in claim 21 wherein said guide opening functions as a stop mechanism wherein said portion of said linkage extending through said opening engages sides of said guide opening to provide limits to said movement of said mouse object, said mouse object moveable in a planar workspace.

23. A mouse interface device as recited in claim 22 wherein said mechanical linkage is provided between said support surface and said grounded surface.

24. A mouse interface device as recited in claim 20 wherein said actuators are voice coil actuators, each of said voice coil actuators including a wire coil integrated with one of said base members of said linkage, wherein said wire coil moves through a magnetic field provided by a plurality of grounded magnets surrounding said wire coil, and wherein a housing providing a flux path surrounds said magnets, each of said wire coils being coupled to an end of a different member of said support linkage, said coils guided through said magnetic field by said linkage.

25. A mouse interface device as recited in claim 24 wherein said sensor detects movement of said members having said wire coils, and wherein said sensor includes an emitter that emits a beam of energy and a detector that detects said beam, wherein both said emitter and said detector of said sensor are coupled to said ground surface.

26. A mouse interface device as recited in claim 24 wherein said base members and said coils pivot about a single axis of rotation.

27. A mouse interface device as recited in claim 21 further comprising a roller coupled to said linkage at said coupling coupled to said mouse object, said roller supporting said mouse object on said ground surface.

28. A force feedback interface device for interfacing with a host computer system implementing a graphical environment, the force feedback interface device comprising:

a user manipulatable object physically contacted and manipulated by a user and moved in two degrees of freedom with respect to a ground surface;

a linkage coupling said mouse object to said grounded surface and allowing movement of said mouse object in said two degrees of freedom, said linkage including a plurality of members, at least one of said members rotatable about an axis;

a plurality of actuators, said actuators providing a force on said mouse object in said two degrees of freedom; and

a sensor detecting movement of at least one of said members of said linkage and outputting a sensor signal indicative of said movement, wherein said sensor includes an emitter that emits a beam of energy and a detector that detects said beam, wherein both said emitter and said detector of said sensor are coupled to said ground surface, and wherein said sensor includes an arc coupled to said member of said linkage rotatable about said axis, said arc including a portion which prevents portions of said beam impinging on said portion to be detected by said detector, and including a strip which directs portions of said beam impinging on said strip to be detected by said detector, wherein said strip is skewed such that different portions of said strip are at different distances from said axis.

29. A force feedback interface device as recited in claim 28 wherein said emitter is positioned on one side of said arc, and said detector is positioned on a different side of said arc.

30. A force feedback interface device as recited in claim 30 wherein said portion of said arc is opaque to block portions of said beam from impinging on said detector, and wherein said strip is transparent to allow said beam to impinge on said detector.

31. A force feedback interface device as recited in claim 28 wherein said emitter is positioned on a same side of said arc as said detector.

32. A force feedback interface device as recited in claim 31 wherein said strip is reflective to reflect said beam to said detector, and wherein said portion of said arc is not reflective such that said beam is not reflected to said detector.

33. A force feedback interface device as recited in claim 28 wherein said actuators include two grounded voice coil actuators, each of said actuators including a wire coil provided on a

different member of said linkage, each of said wire coils pivoting about a single axis of rotation, wherein each of said actuators includes a plurality of grounded magnets in a flux path housing surrounding said wire coil, wherein said housing of one of said actuators is positioned above and contacting said housing of said other actuator, and wherein each of said actuators is receptive to a control signal operative to control an output force from said actuator on said member having said wire coil.

34. A force feedback interface device as recited in claim 33 wherein said sensor is a first sensor and further comprising a second sensor including an emitter, detector, and arc, each of said sensors coupled to one of said members of said linkage.

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